

A Value of Solar Externality Analysis for Michigan

University of Michigan
Dow Sustainability Fellows Project
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Outlining today's presentation

- Project Overview
- Analysis Results
 - Fuel Price Hedge
 - Environmental Benefits
 - Reactive Supply & Voltage Control
- Recommendations



Project Overview



Our Dow fellowship project evaluated solar externalities in Michigan

Made possible by The Dow Chemical Company, the Dow Sustainability Fellows Program at the University of Michigan supports graduate students who are committed to finding sustainability solutions

Fellows form interdisciplinary teams to develop a white paper for a client on a sustainability challenge of the team's choosing

Our Project for the Michigan PSC:

- **Value of Solar Externality Analysis for Michigan**
- Critique of Minnesota Value of Solar Methodology
- Rooftop Solar Penetration Analysis for Michigan



Solar externalities are benefits & costs that parties beside the homeowner experience

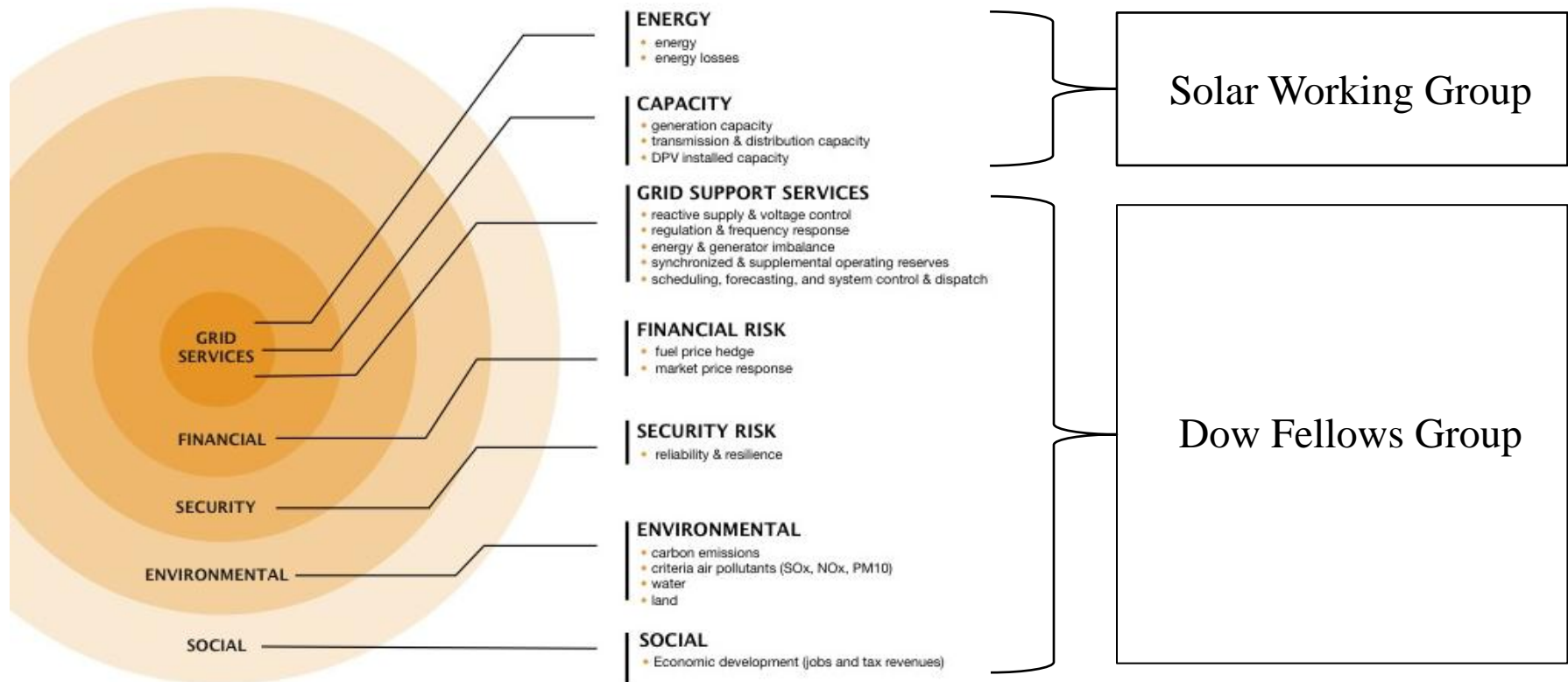
An externality is a benefit or cost that affects a party who did not choose to incur that benefit or cost

Solar externalities are benefits or costs that other parties besides the homeowner experience. Other parties include:

- Utilities
- Ratepayers
- Society



Solar externalities are a critical piece of a complete value-of-solar analysis



Our project analyzed the fuel price hedge, environmental benefits and reactive power & voltage control benefits of distributed solar generation

Lena Hansen, Virginia Lacy & Devi Glick. A Review of PV Benefit & Cost Studies. Rocky Mountain Institute 2013.

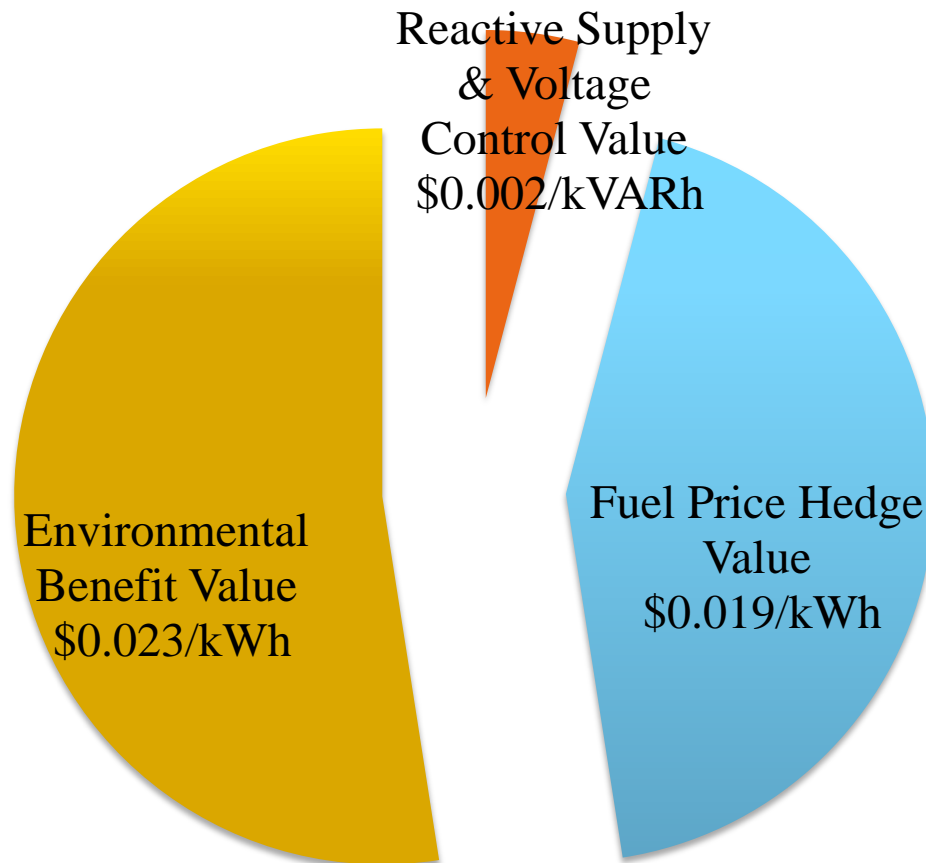


Analysis Results



The solar externalities analyzed provide an additional \$0.042/kWh of value

Michigan Solar Externality Analysis Results



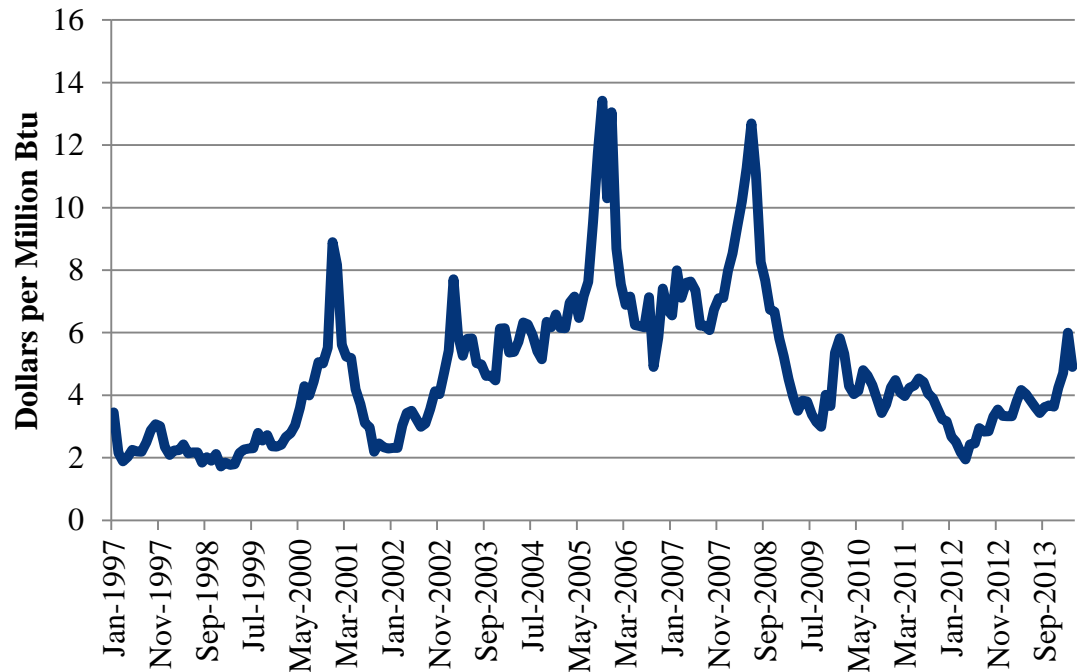
The fuel price hedge is the utility's cost to insure future power prices are fixed

Unlike fossil-fuel generation, DSG produces constant-cost power. Therefore, DSG provides a hedge against volatile fossil fuel prices

Fuel price hedge: The cost that a utility would incur to guarantee that electricity supply-costs are fixed

The fuel price hedge is a financial risk that ratepayers currently bear in Michigan

Historic Henry Hub Natural Gas Spot Price



The fuel price hedge is calculated by setting aside the entire fuel obligation today

The fuel price hedge is calculated by comparing the difference between an investment with fuel price uncertainty to one with fuel price certainty. For example, an utility could set aside the entire fuel cost obligation upfront, buying a risk free instrument and entering into a futures contract for future fuel needs.

$$\text{Annual fuel price hedge} = (E * H * P) / (1 + R)$$

–E = Distributed Solar Electricity Generated

–H = Heat Rate of the Offset Generation

–P = Price of the Offset Generation Fuel

–R = Risk-Free Interest Rate

Separate calculations must be completed for offset coal and natural gas generation. In 2013, the marginal generation source during solar generation was ~65% coal. In 2038, the marginal generation source is expected to be 66% natural gas due to coal retirements.

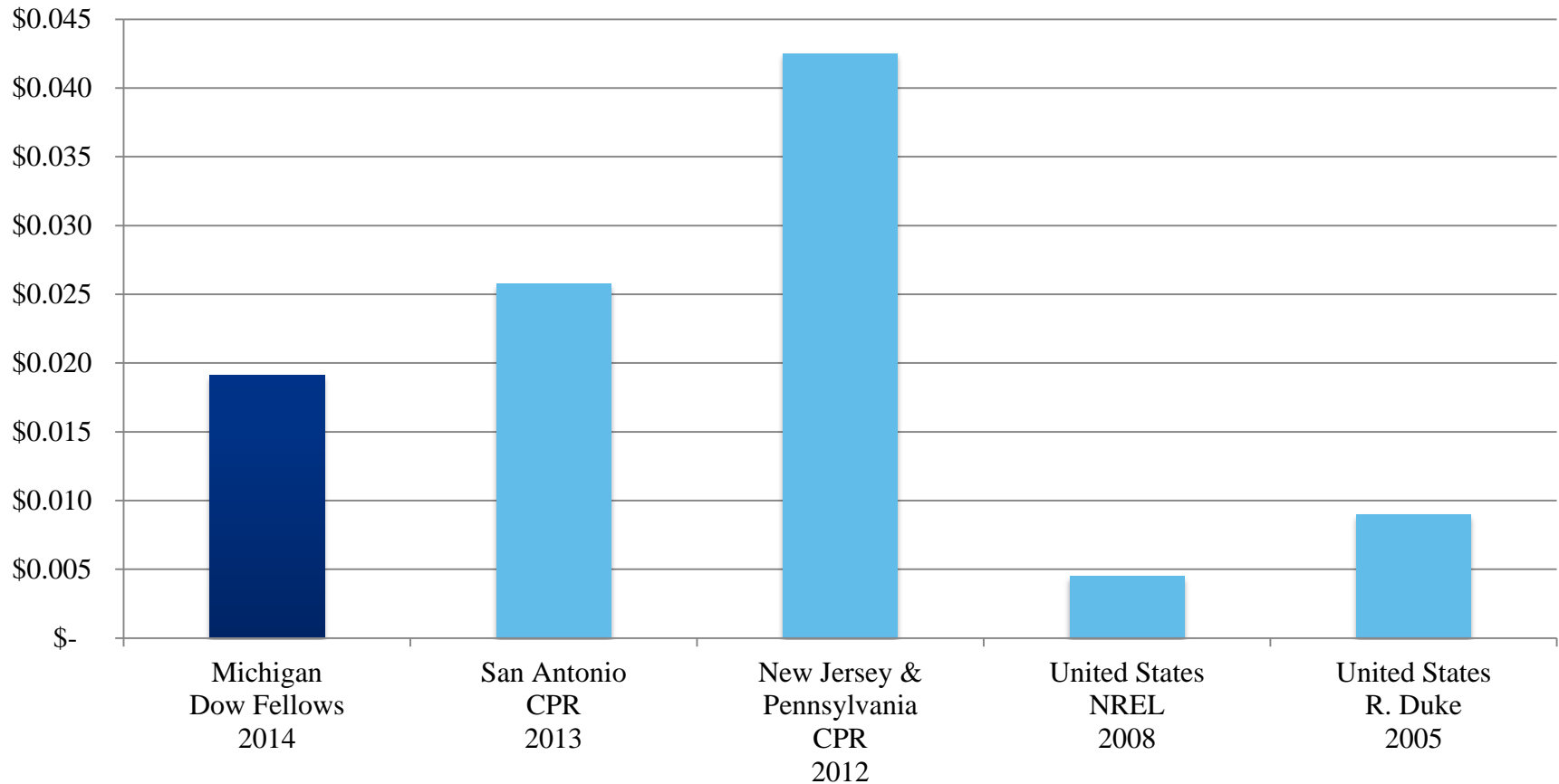
$$\text{Total fuel price hedge} = \Sigma \text{Annual fuel price hedge}$$

$$\text{Fuel price hedge value} = \text{NPV}(\text{Total fuel price hedge}) / \text{Total E}$$



The fuel price hedge value for Michigan is \$0.019/kWh, in-line with other studies

Fuel Price Hedge Value



Environmental benefits partially come from reducing CO2 emissions

Environmental benefits include reducing CO2 emissions, criteria air pollutants, water pollution and land use. VOS analyses calculate the value of avoided carbon pollution by using the Federal Government's social cost of carbon

Michigan is ranked 10th in state CO2 emissions

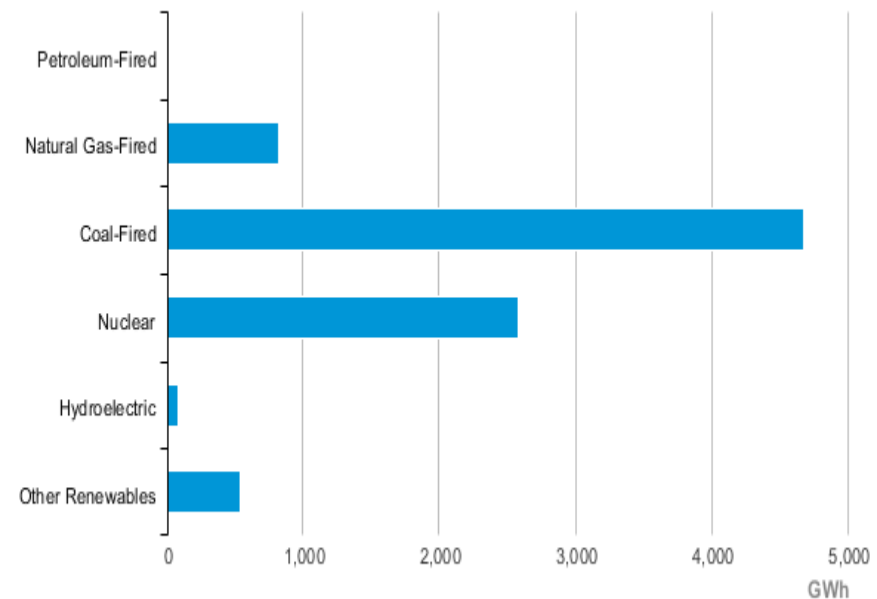
–Total emissions = 2.5 share of U.S. emissions

–Electric power emissions = 3.1% share

Benefits to reducing CO2 emissions:

1. Reduce future compliance costs, carbon taxes and other fees
2. Mitigate the health and ecosystem damage from CO2 emissions

Michigan Net Electricity Generation by Source, Nov. 2013



 Source: Energy Information Administration, Electric Power Monthly



The value of avoided carbon emissions is calculated by applying the social cost of carbon

The environmental benefits analysis considered the carbon emissions avoided by using solar generated electricity instead of power from coal and natural gas plants.

$$\text{Annual CO}_2 \text{ Value} = E * H * C * P$$

–E = Distributed Solar Electricity Generated

–H = Heat Rate of the Offset Generation

–C = CO₂ Emissions from Offset Generation

–P = Social Cost of Carbon

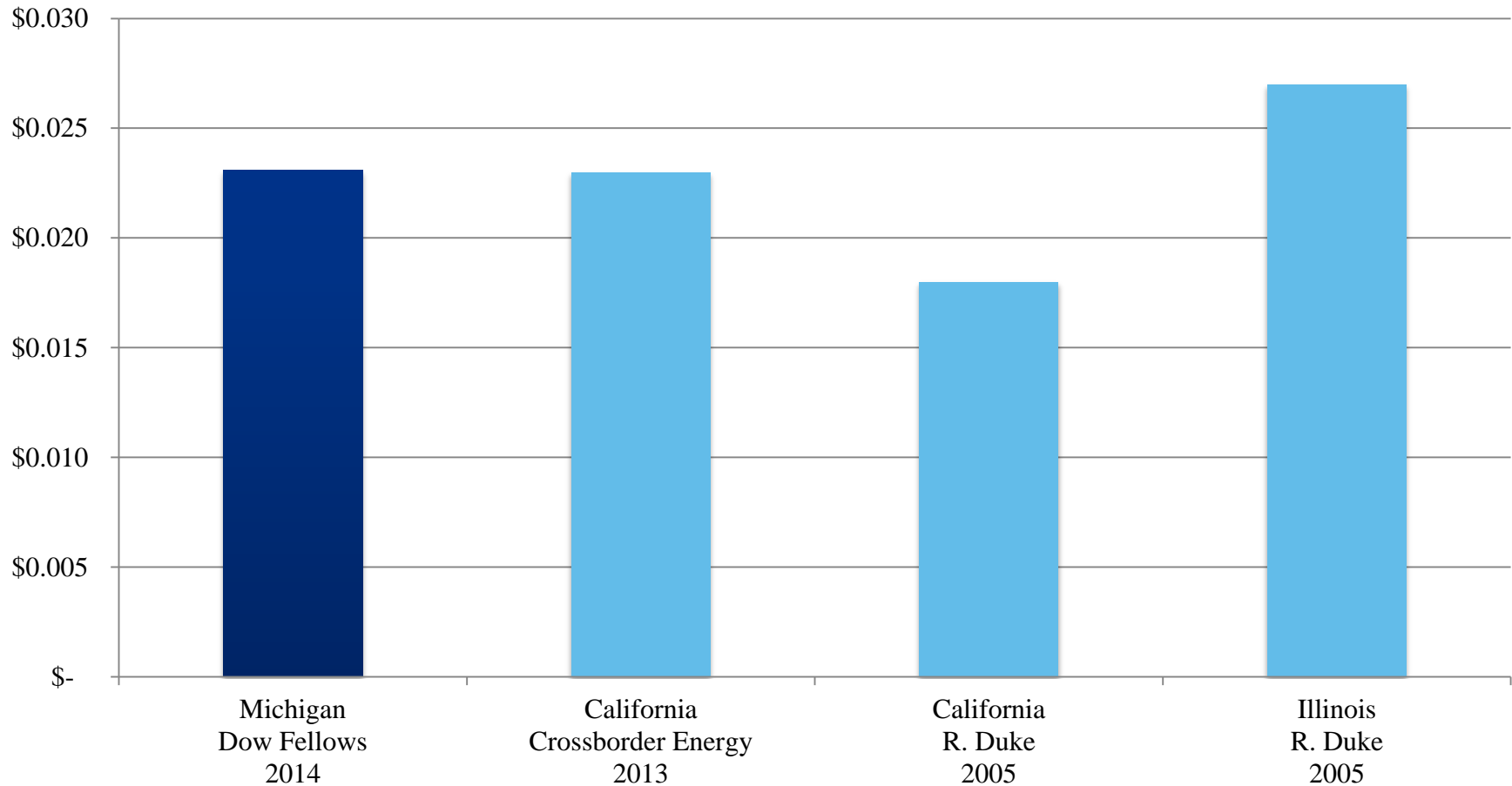
$$\text{Total CO}_2 \text{ Emissions Value} = \Sigma \text{Annual CO}_2 \text{ Emissions Value}$$

$$\text{CO}_2 \text{ Emissions Value} = \text{NPV}(\text{Total CO}_2 \text{ Emissions Value}) / \text{Total E}$$



The environmental value for Michigan is at least \$0.023/kWh, similar to other studies

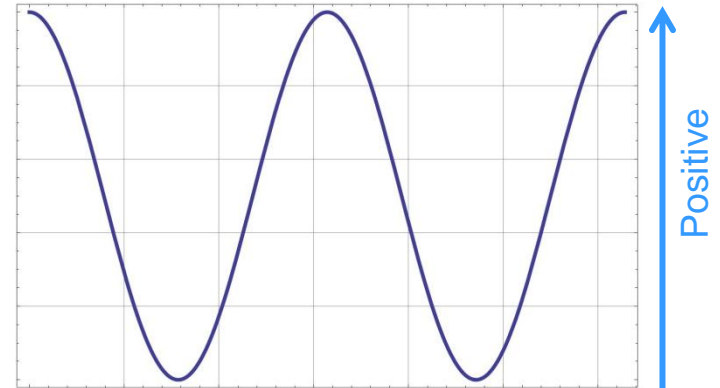
Environmental Benefits Value



There are two types of power: Active power and reactive power

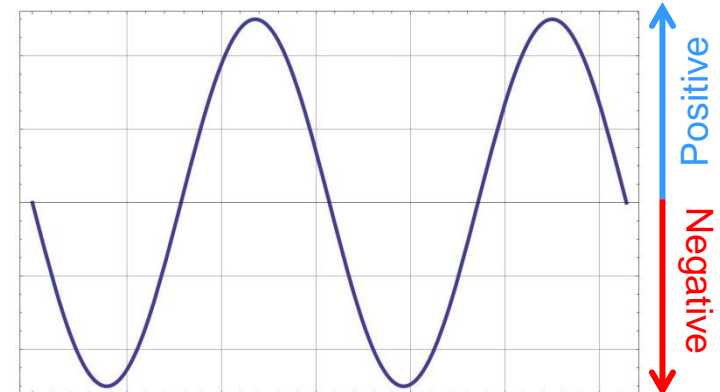
Active Power

- Always positive
- Measured in kW
- Useful for loads
- Moderate effect on voltage



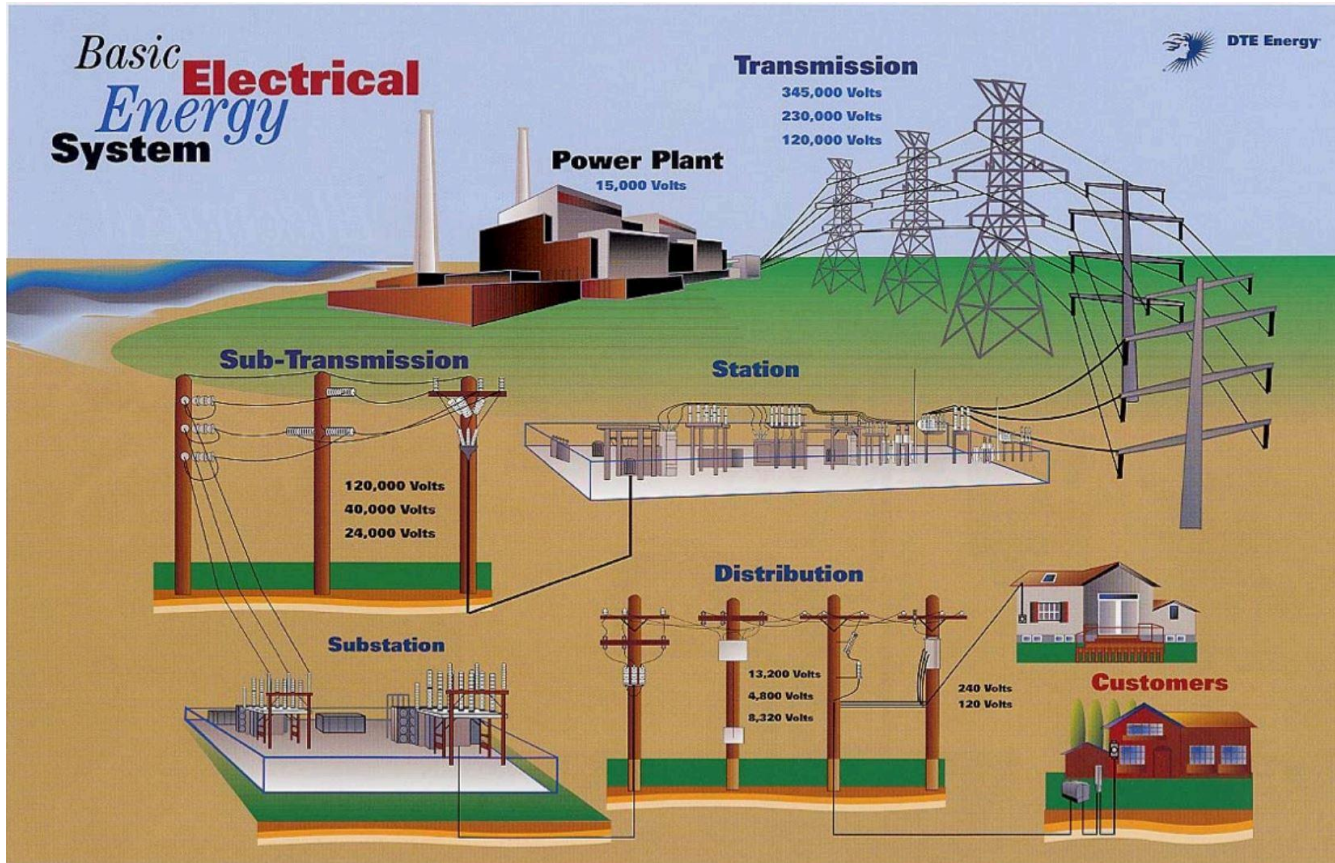
Reactive Power

- Can be positive and negative
- Measured in kVAR
- Cannot be consumed by loads
- Significant effect on voltage
 - Increase voltage (Inject reactive power)
 - Decrease Voltage (Draw reactive power)

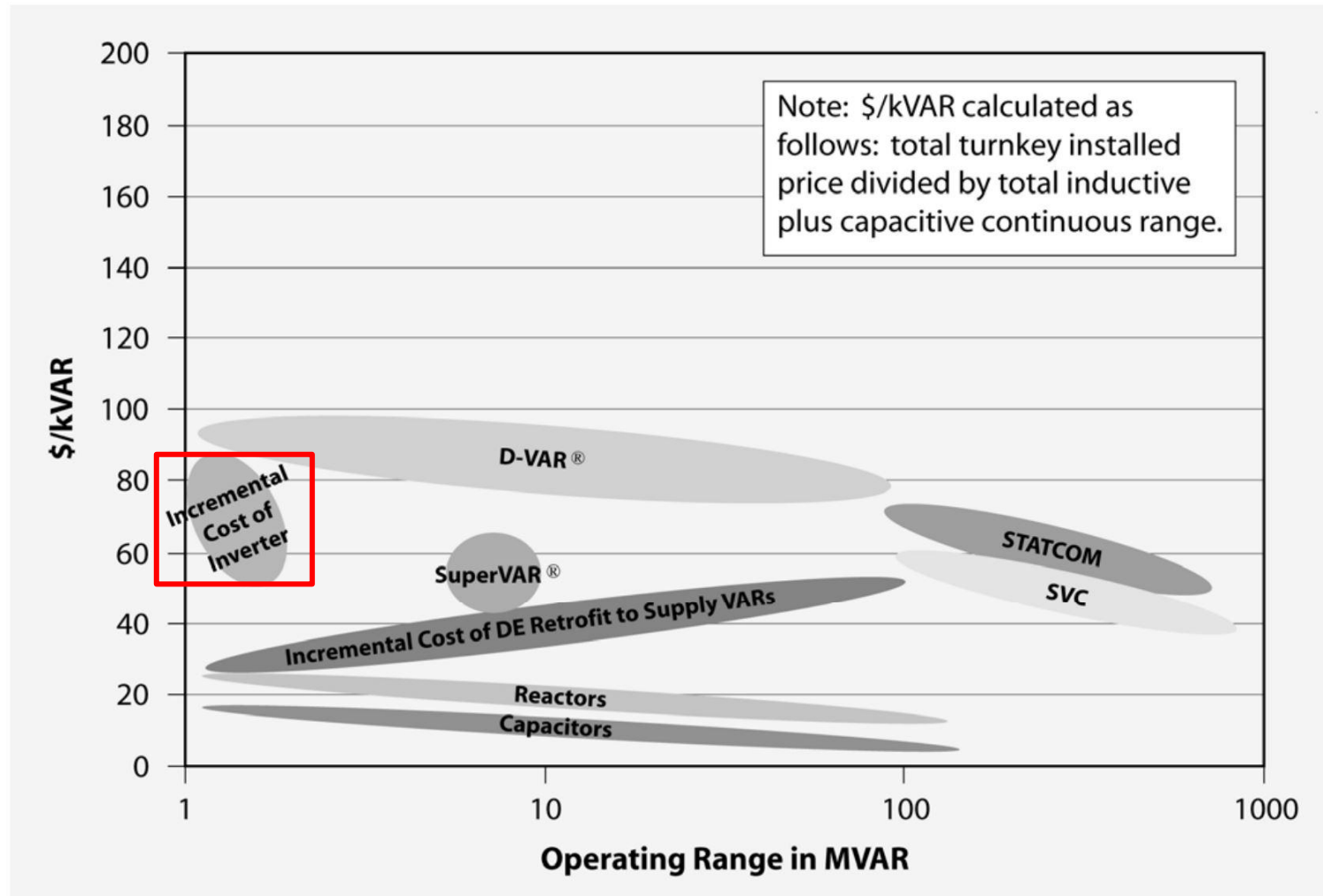


Voltages on the electric grid must be in a narrow range in order to provide usable power

Home appliances and consumer electronics expect voltages of $120\text{ V}_{\text{RMS}}$



There are many technologies that provide reactive power for voltage support including smart inverters for DSG; However, smart inverters are not the most cost-effective yet



C. Tufon, A. G. Isemonger, B. Kirby, J. Kueck and F. F. Li. A tariff for reactive power. Oak Ridge National Laboratory 2008.



Voltage control from smart inverters for DSG are worth \$0.0018/kVARh

Base Rate = \$0.00056/kVARh

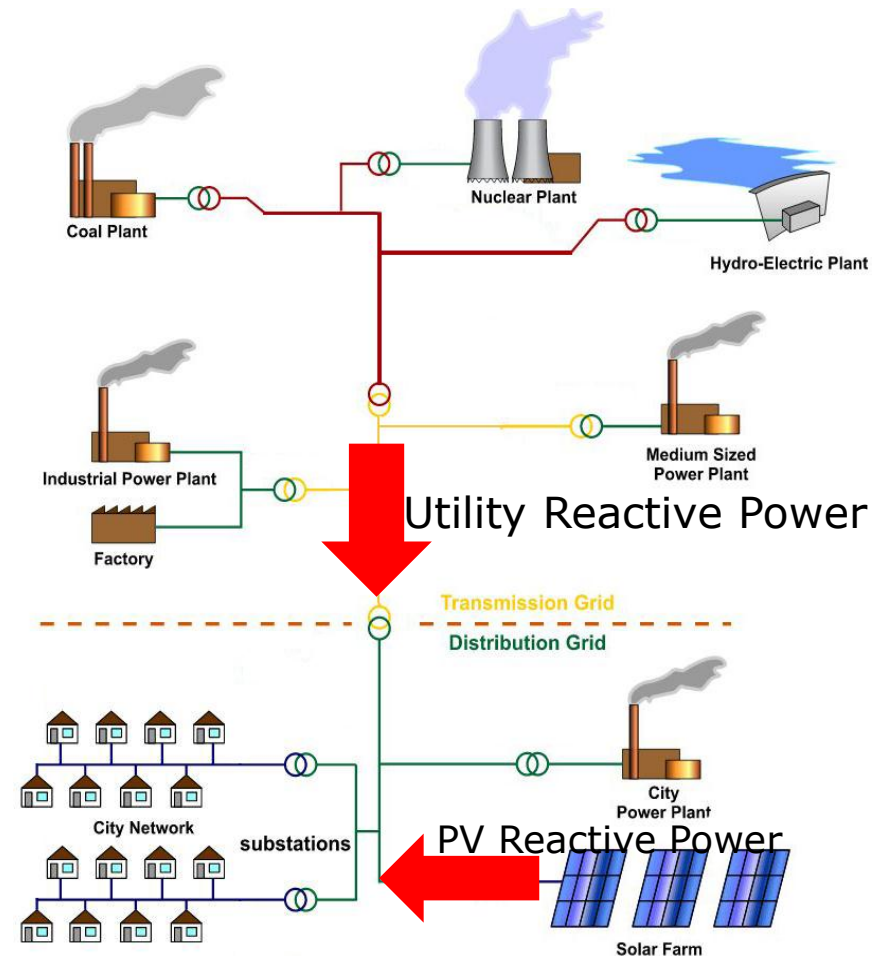
- In Michigan there is no market for reactive power
- The base rate is the average of FERC-approved reactive power rates for voltage support

Additional Sources of Value:

- 1.Reduced Lines Losses
 - Local supply of reactive power
- 2.Increased Transmission Capacity
 - Critical during congestion
- 3.Increased Maximum Transfer Capability
 - Enables utilities to relocate their demand to cheaper generators.

Total Value = \$0.0018/kVARh

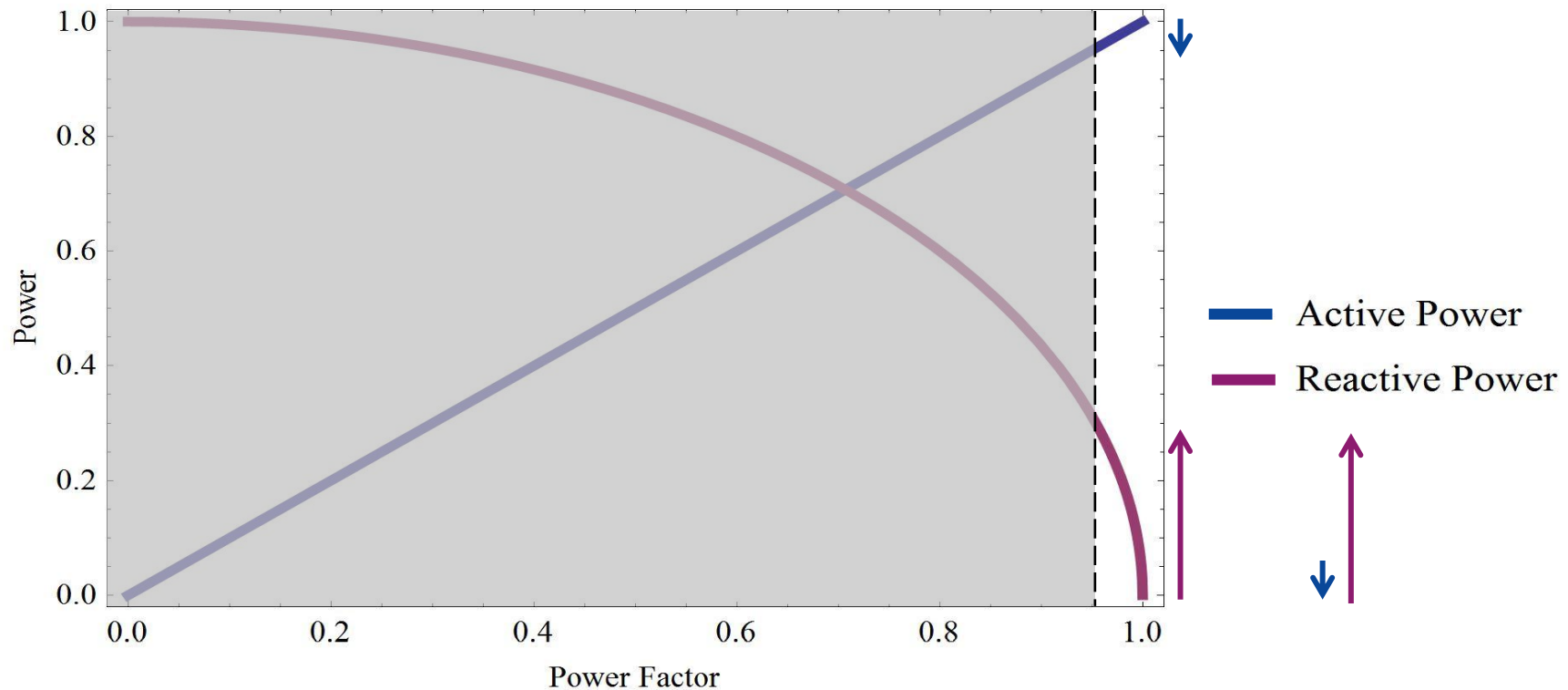
- Total Value = Base Rate + Additional Sources of Value



F. F. Li, J. Kueck, T. Rizy and T. King. A preliminary analysis of the economics of using distributed energy as a source of reactive power supply. Oak Ridge National Laboratory. 2006

This value is tiny because reactive power is cheap to produce by conventional generation

Due to the nature of AC power, generators only have to sacrifice a small amount of active power to generate a large amount of reactive power. As a result, the most cost-effective way to provide voltage/reactive support is to use the conventional voltage support devices such as capacitor/reactor banks or solid-state “static” compensators



Additionally some voltage fluctuations comes from DSG so smart inverters should be utilized to minimize the impact of solar interconnection

In reality, it is difficult to identify the source of voltage fluctuations. For places with high DSG penetration, advanced inverters can be used to mitigate voltage fluctuations caused by the DSG in the first place.

In conclusion, advanced inverters have been shown to greatly enhance the reliability of renewable interconnection. However, the economical impact of localized reactive supply is not significant.



Recommendations



The Michigan PSC should include solar externalities in a VOST policy

Solar externalities have value; our analysis found that in Michigan they are worth at least \$0.042/kWh

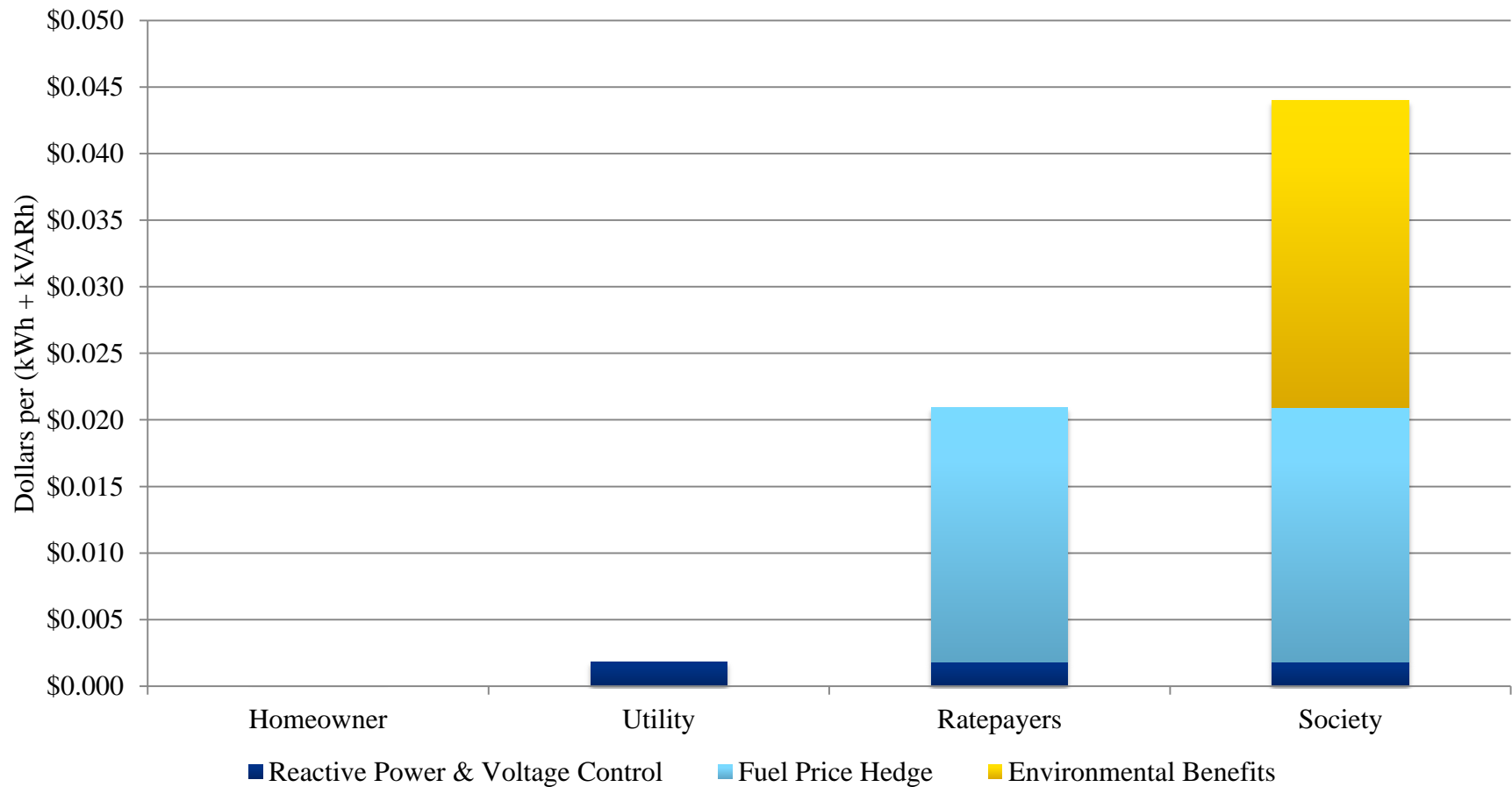
We recommend:

1. The PSC include solar externalities if the commissioners choose to move ahead with a value-of-solar tariff policy
2. The PSC conduct a complete VOS analysis for Michigan by analyzing all solar externalities



The value of solar externalities differs for each stakeholder

Solar Externality Value to Stakeholders



Questions?

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